time of stimulation and that of contraction, and are not influenced by ordinary anesthetics.

The majority of the muscles in a sea-anemone respond quickly under the influence of the nerve-net and enter into a state of enduring contraction (tonicity). This is as characteristic of a small fragment of an animal, provided it contains a nerve-net as well as muscle, as it is of a whole animal. So striking is this excessive tonicity in the muscle of sea-anemones that it has been assumed to be their exclusive function and they have recently been regarded (Jordan) as animals incapable of ordinary reflexes. Such a conclusion, however, seems to be too sweeping.

If a specimen of Metridium is allowed to expand fully and a small piece of meat is placed on its tentacles, the mouth and oesophagus soon open and the sides of the column are marked by a few pronounced vertical grooves. After the food has been swallowed the grooves disappear and the oesophagus closes. The opening of the oesophagus is brought about by the contraction of the transverse muscles of the mesenteries whose action is so precisely associated with the appropriate stimulation of the tentacles that it carries with it all the signs of a reflex. It therefore seems clear that among the muscles in sea-anemones there are not only independent effectors, and tonus muscles associated with nerve-nets, but neuromuscular combinations that exhibit true reflex action.

The detailed paper will be published in the *Journal of Experimental Zoölogy*.

PRELIMINARY EVIDENCE OF INTERNAL MOTION IN THE SPIRAL NEBULA MESSIER 101

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Inasmuch as data for the proper motions of stars, determined by photographic methods, have been rapidly accumulating since the beginning of the century, it may seem strange that the first results for nebulae should have been published only in 1915. It must not be forgotten, however, that photographs of nebulae require much longer exposures, and that, even with the best plates, the measures are more difficult and less accurate, because of the unsymmetrical character of the points and condensations upon which settings must be made, than is the case with the round images of stars. A given point in a nebula may be bisected quite differently on different plates and the measures

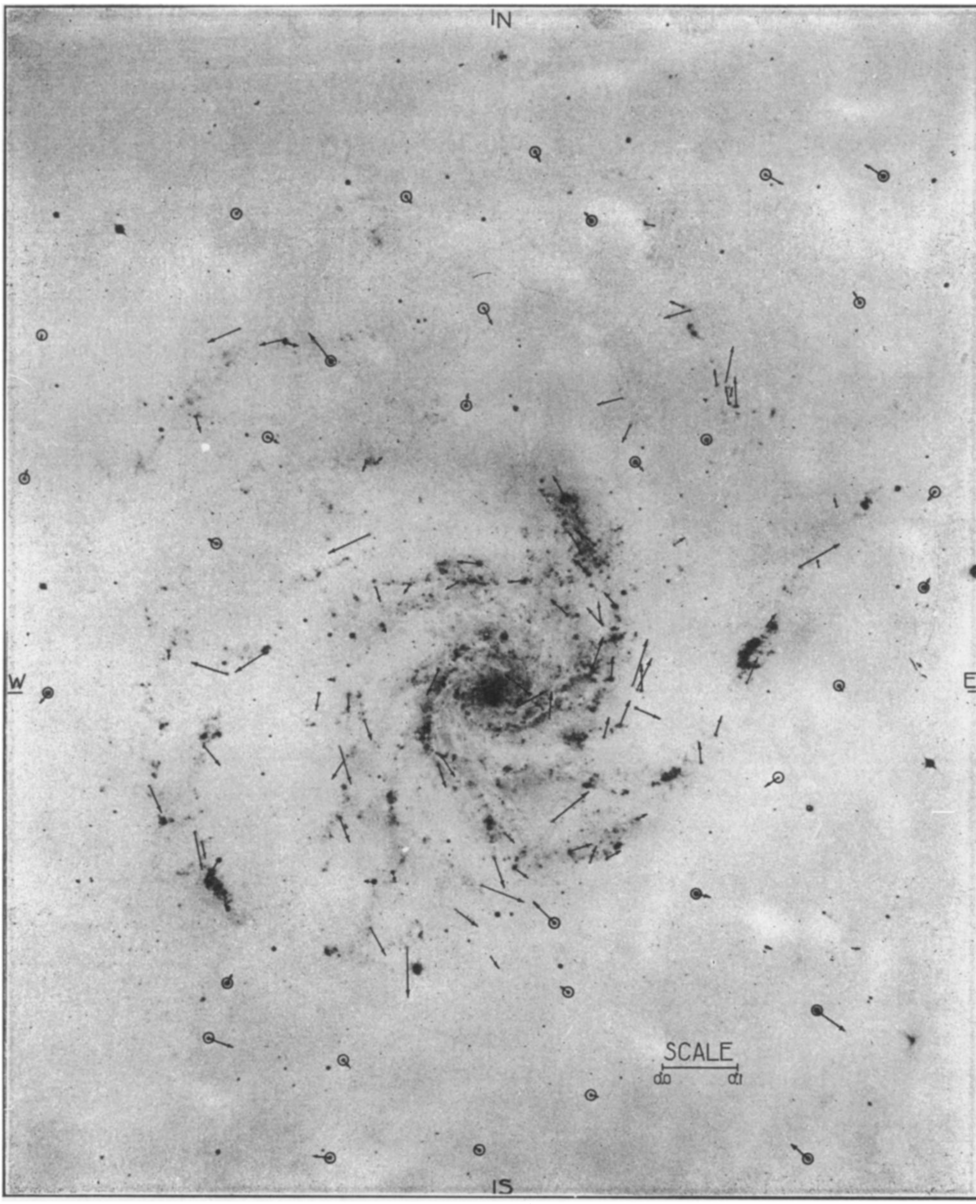
will therefore fail to reveal the proper motion with anything like the precision attainable in a star cluster, for instance. The difficulty of bisection may, however, be largely overcome by measuring corresponding points on different plates in immediate succession.

For such measures the monocular arrangement of the stereocomparator is an admirable instrument, and that it is capable of yielding very accurate results has already been pointed out.[1] When therefore Mr. Ritchey placed at my disposal for measurement two excellent plates of the spiral nebula Messier 101, taken in 1910 and 1915, there was no question but that the stereocomparator was the best instrument for the purpose.

Although the results showed striking evidence of internal motion, the necessity of additional plates was strongly felt. At my request Dr. Curtis kindly placed at my disposal three photographs made with the Crossley reflector of the Lick Observatory, one by Keeler in 1899, one by Perrine in 1908, and one by Curtis himself in 1914.

The pair taken by Mr. Ritchey was completely measured twice, the Lick pairs 1914–1899 and 1908–1899 once each; each pair was measured in four positions, with east, west, north and south, respectively, in the direction of increasing readings of the micrometer screw. On the Mount Wilson plates 87 nebulous points were measured; on the first Lick pair 46, and on the second 69 points, while on all the pairs the same 32 stars were used for comparison purposes. The measures and reductions, which will be published in full in the *Astrophysical Journal*, were made substantially in the manner described in my recent paper on the determination of stellar parallaxes,[2] the principal difference being that the quadratic terms could not here be neglected and were accordingly included in the reductions.

The results showed that to each pair of plates could be given the same weight, and the direct mean of the values found for the proper motions of each point is therefore used in the discussion. The resulting motions, which are those relative to the mean of the 32 comparison stars, are due partly to a motion of translation of the nebula as a whole, and partly to a possible internal motion. The annual motion of translation, which was derived by three different methods of reduction, was found to be: $\mu_\alpha = +0''.005$, $\mu_\delta = -0''.013$. Subtracting these from the total motions, the results are what may be called the internal motions. The accompanying plate shows these mean internal motions for each of the 87 points of the nebula. The individual motions for the comparison stars, which are surrounded by circles are also shown. The scale for the annual motions is given at the bottom of the plate. The



INTERNAL MOTIONS IN MESSIER 101

The arrows indicate the direction and magnitude of the mean annual motions. Their scale (0".1) is indicated on the plate. The scale of the nebula is 1 mm. = 10".5. The comparison stars are enclosed in circles.

density of the center of the nebula has been reduced to show the motions more clearly.

If the results as illustrated on the plate could be taken at their face value, they would certainly indicate a motion of rotation, or possibly motion along the arms of the spiral. Without expressing a final opinion as to the character of the motion, which must be determined by future work, it may be of interest to examine the evidence afforded by the existing material. Comparing the motions with the directions of the branches of the spirals, we find from 52 points in which this direction can be specified with fair accuracy, that the mean divergence of the motions is 7° ± 4° toward the concave side of the spirals.

To discuss the internal motions from the standpoint of rotation, they were analyzed into two components, along and perpendicular to the radius, the latter for convenience being spoken of as the rotational component.

The results are as follows:

78 points have a left-hand motion (N. W. S. E.), only 9 moving right-handedly; 58 points appear to be moving outward, while 28 show motion inward. The rotational motion is the larger in the majority of cases, viz., 63 points. The mean rotational motion is 0."022 left-handed; the mean radial motion is 0."007 outward. The probable reality of the result is indicated by the satisfactory agreement of the pairs of plates, as shown by the following summary.

$\mu_{rot.}$	$\mu_{rad.}$		
+0."021	+0."004	Ritchey	1910 and 1915
+0.032	+0.012	Ritchey	1910 and 1915
+0.012	+0.007	Keeler and Curtis	1899 and 1914
+0.017	+0.006	Keeler and Perrine	1899 and 1908

The measures indicate a small but scarcely reliable decrease of rotational motion with increasing distance from the center, as shown by the following table:

Distance from Center	$\mu_{rot.}$	No. of Points
<3.'1	0."024	19
3.1 to 5.0	0.028	29
5.1 to 7.0	0.014	18
>7.0	0.019	21

The annual rotational component of 0.022 at the mean distance from the center of 5′ corresponds to a rotational period of about 85,000 years. If we knew the parallax of the nebula, and if we could assume that the motions and the distances of the points from the center are

mean values for elliptical orbits, the central mass could be calculated. Even though this assumption may be far from the truth it seems worth while to accept certain more or less hypothetical values of the parallax in order to get any idea of the order of the masses with which we are concerned.

Two estimates as to the parallax can be made, (1) by comparing the average motion of translation of 66 spiral nebulae, as given by Curtis,[3] with those of the stars; (2) by comparing these cross-motions with the observed radial velocities of the few spirals for which such results are known. In the first case we derive a parallax of $0\overset{''}{.}005$; in the second, of $0\overset{''}{.}0003$. The corresponding central masses are in both cases very large, viz., 30,000 and 140,000,000 times that of the sun. Various objections to the acceptance of these results, even as rough guesses can be made, but they are the best we have at the moment. The corresponding orbital motions would be 21 and 345 km./sec. These quantities do not seem absurd if we remember that Wolf by spectroscopic methods found a rotational component of $\pm$ 100 km./sec. in Messier 81.[4]

As the detailed results will soon be published I will only mention two more points which seem to confirm the reality of the motions. Mr. Nicholson very kindly spent much time in making check-measures on the plates taken by Mr. Ritchey, both with the stereocomparator and with another measuring machine in which two microscopes were mounted in such a way that they were directed toward corresponding points on the two plates, mounted on the same plate-carrier and moved by the same micrometer screw. His measures give satisfactory confirmation of my own results. Further, I have measured two plates of Messier 81, taken by Mr. Ritchey in 1910 and 1916, which show motion similar to that found above for Messier 101. It seems hardly necessary to suggest the importance of internal motions, such as are indicated here, in connection with the Chamberlin-Moulton hypothesis as to the origin of spiral nebulae, and it is to be hoped that material will soon be available for a fuller discussion.

[1] *Astronomical Journal*, **27**, 140 (1912).

[2] *Mt. Wilson Contr.*, No. 111, 4 seq., 1916.

[3] *Publications Astronomical Society Pacific*, **27**, 216 (1915).

[4] *Vierteljahrsschrift Astronomischen Gesellschaft*, **49**, 162 (1914).